THE FRESH-WATER LOCHS OF SCOTLAND.[1]

THE introduction to this paper, published in the *Geographical Journal*, includes the correspondence that passed between the Royal Societies of London and Edinburgh and Her Majesty's Treasury in 1883 and 1884, relative to the survey by a Government Department of some of the inland lakes of Scotland.

The weighty arguments brought to bear upon the Government by these learned societies failed in their object, and the Government declined to undertake the proposed surveys. In these circumstances the authors determined a few years ago to make a systematic survey of all the fresh-water lochs of Scotland, and the present paper is the first instalment in the publication of their results, dealing with a compact series of lakes directly or indirectly connected with the water-supply to the city of Glasgow, viz. Lochs Katrine, Arklet, Achray, Vennachar, Drunkie, Voil, Doine and Lubnaig, which form part of one united drainage system having its outflow by the River Teith.

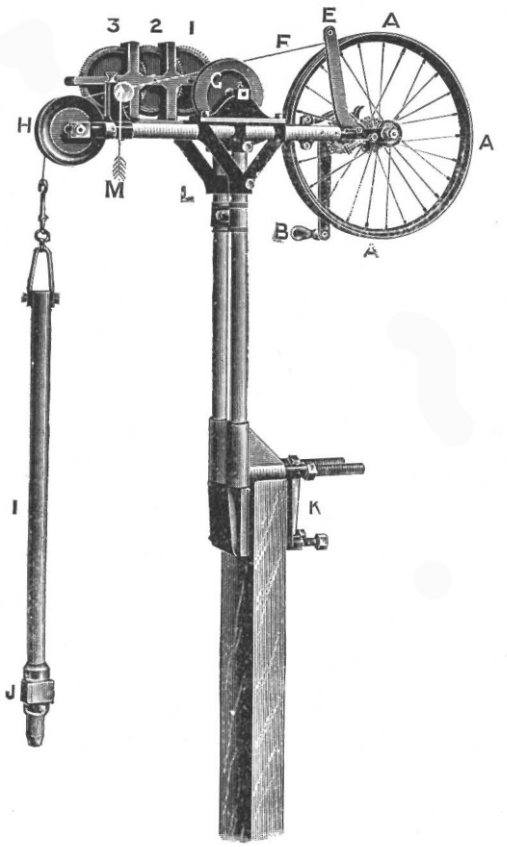

FIG. 1.—F. P. Pullar's sounding machine.

In order to overtake the large amount of work contemplated, involving an immense number of soundings, within a reasonable time, it was necessary to have a portable wire sounding machine adapted for rapid work in small rowing boats. Mr. Pullar designed, and had made, a sounding machine (see Fig. 1), which is described and figured; this apparatus is admirably adapted for the purpose in view, and with it all the soundings in the different lakes were taken.

The total number of soundings recorded in the paper, taken in the eight lochs mentioned, was 2422, the number varying from 775 in the largest (Loch Katrine) to 90 in the smallest (Loch Doine). These soundings were laid down in position on the large scale (six-inch) Ordnance Survey maps, and contour-lines of depth drawn at certain intervals, from which with the aid of the planimeter the cubic mass of water in each loch was calculated. The soundings show that Lochs Katrine, Arklet, Achray, Voil and Doine form each a single basin, while in Lochs Lubnaig, Drunkie and Vennachar the irregularities of the bottom cut up the deep parts of the lochs into separate basins.

The most important of the lakes under consideration is the well-known Loch Katrine, which is eight miles in length, one mile in maximum width, with an area of $4\frac{3}{4}$ square miles. The greatest depth, 495 feet ($82\frac{1}{2}$ fathoms), was found much nearer the eastern than the western end, so that a section drawn down the centre of the loch from west to east (see Fig. 2) shows a gradual increase of depth for nearly four-fifths of the total length, and then a more rapid rise of the bottom towards the eastern end. A section across the loch from north to south (see Fig. 3) shows the deeper part at the point chosen for the section nearer the southern than the northern shore. The mean depth of the loch, *i.e.* the cubic mass of water divided by the area, is 199 feet. The surface of the loch lies at an elevation of 364 feet above the sea, hence a considerable portion of the bottom (over one square mile) falls below the level of the sea; in this respect Loch Katrine differs from all the other lochs treated of. In connection with the water-supply to Glasgow, Loch Katrine was raised four feet above its previous level, and it is now in process of being raised an additional five feet.

Loch Arklet is a small Highland loch situated between Lochs Katrine and Lomond, at an elevation of 455 feet above the sea. It is over a mile in length, nearly half a mile in maximum width, and covers an area of about one-third of a square mile. The greatest depth, 67 feet, was found nearer the western than the eastern end; the mean depth is 24 feet. Loch Arklet at present belongs to the watershed of Loch Lomond, but the Corporation of Glasgow have power to divert its waters into the Loch Katrine watershed, with the view of increasing the supply of water to that city.

Loch Achray is situated between Lochs Katrine and Vennachar, at an elevation of 276 feet above the sea. It receives the outflow from Loch Katrine and flows into Loch Vennachar, the level of which is six feet lower. Loch Achray is about $1\frac{1}{4}$ miles in length, and one-third of a mile in maximum width, covering an area of about one-third of a square mile. The greatest depth, 97 feet, was recorded in two places approximately in the centre of the loch; the mean depth is 36 feet.

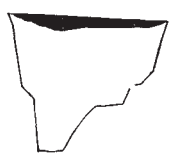

FIG. 3.—Transverse section of Loch Katrine. The black portion shows the true slopes; the outline shows the slopes exaggerated ten times.

Loch Vennachar is about four miles in length, with a maximum breadth of less than three-quarters of a mile, and covers an area of over $1\frac{1}{2}$ square miles. The greatest depth, 111 feet, is situated approximately in the centre of the loch; the mean depth is $42\frac{1}{2}$ feet. Loch Vennachar has been raised five feet nine inches in connection with the Glasgow water-supply, for the purpose of providing compensation water to the River Teith.

FIG. 2.—Longitudinal section of Loch Katrine along the axis of maximum depth. The black portion shows the true slopes; the outline shows the slopes exaggerated ten times.

[1] "A Bathymetrical Survey of the Fresh-water Lochs of Scotland." By Sir John Murray, K.C.B., D.Sc., F.R.S., and Fred. P. Pullar, Esq., F.R.G.S. Part i. The Lochs of the Trossachs and Callander District.

Loch Drunkie is a peculiar irregular little Highland lake, shut in on all sides by high hills, situated, at an elevation of 416 feet above sea-level, a quarter of a mile to the south of Loch Vennachar, into which it flows. It is remarkable in shape, a quadrangular body throwing out three arms in different directions; the maximum length is over a mile, the maximum width of the body over a quarter of a mile, and the area nearly a quarter of a square mile. The greatest depth, 97 feet, was found near the base of the north-eastern arm; the mean depth is 36 feet. Loch Drunkie was raised twenty-five feet in connection with the Glasgow water-supply, for the purpose of supplying compensation water to the River Teith.

Lochs Voil and Doine formed at no distant date a continuous loch, which has been divided into two portions by the material deposited by the rivers. The level of these lochs being fifty feet higher than that of Loch Katrine, it has been suggested that an additional supply of water to Glasgow can be obtained by means of a tunnel from Loch Doine to Loch Katrine through the intervening hills. Loch Voil is over 3½ miles in length, about one-third of a mile in maximum width, and covers an area of nearly nine-tenths of a square mile. The greatest depth, 98 feet, was found towards the western end; the mean depth is 41 feet. *Loch Doine is nearly a mile in length, and over a quarter* of a mile in maximum breadth, with an area of nearly a quarter of a square mile. The greatest depth, 65 feet, was found towards the eastern end; the mean depth is 33 feet.

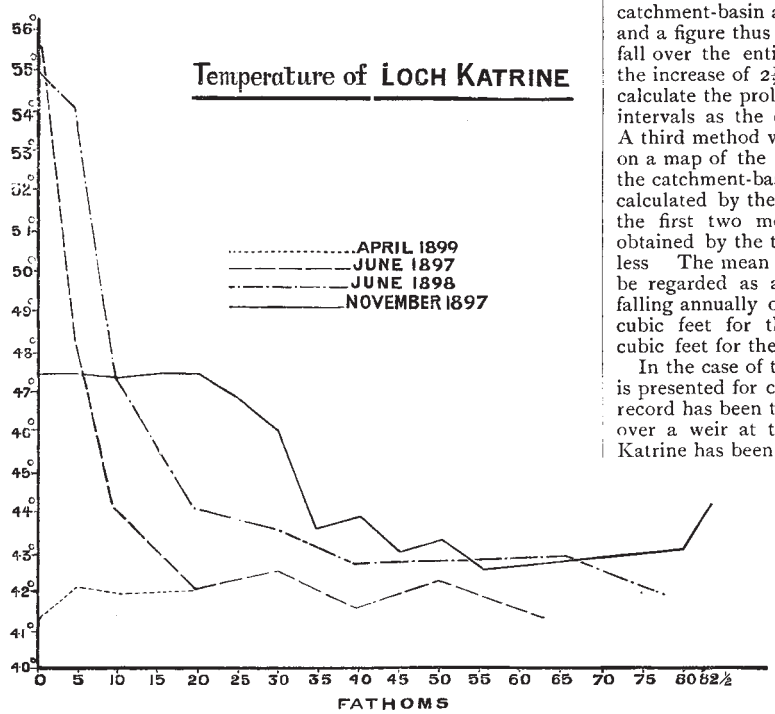

FIG. 4.—Temperature of the water in Loch Katrine.

Loch Lubnaig is one of the most interesting of the lochs under consideration, the configuration of the bottom being much more irregular than in any of the others. It receives the outflow from Lochs Doine and Voil, its level being nine feet lower (405 feet above sea-level). The greatest depth, 146 feet, was found approximately near the centre of the loch; the mean depth is 42¾ feet. The contour-lines of depth do not follow the contour of the loch, hollows and ridges alternate with each other, and in some places comparatively deep water is found close to the shore, while in other places shallow water extends a considerable distance from shore.

The deposits forming on the floor of these lochs are described in detail, and the numerous temperature observations taken at the surface and at various depths down to the bottom (some of which were taken as recently as March 1900) are fully discussed. The serial temperatures taken in Loch Katrine are shown graphically in Fig. 4. The relation between the variation of temperature and the size and depth of the lochs is pointed out, and shows how much more suitable a large deep lake is, as a source of water-supply, than a shallow basin, ensuring a relatively low temperature in summer and a relatively high temperature in winter. Interesting observations were made on the pelagic and other organisms in the various lochs, and on their variation with the season, certain species being obtained in abundance at certain seasons and absent or rare at other seasons.

The amount of rain falling annually on the drainage areas of these lochs was estimated by three methods, the lochs being grouped into two series, viz. Lochs Katrine, Achray, Drunkie and Vennachar, which have their outlet at the eastern end of Loch Vennachar, forming one series; and Lochs Doine, Voil and Lubnaig, which have their outlet at the southern end of Loch Lubnaig, forming the other series. The readings of the rain-gauges at all the observing stations within and near the catchment-basins of these lochs were grouped together into two series corresponding with the two series of lochs indicated, and the average annual rainfall at the average height of the gauges calculated for each series. By the first method, 2½ per cent. of annual rainfall was added for each 100 feet of mean height of the catchment-basin above the average height of the rain-gauges, and a figure thus obtained representing the average annual rainfall over the entire catchment-basin. By the second method, the increase of 2½ per cent. per 100 feet of height was used to calculate the probable annual rainfall at the same heights and intervals as the contour-lines on the Ordnance Survey maps. A third method was afforded by drawing lines of equal rainfall on a map of the district. The total amount of rain falling on the catchment-basins of the two series of lochs indicated was calculated by these three methods, and the results obtained by the first two methods agree very closely, while the results obtained by the third method were in each case considerably less The mean obtained by the three methods may probably be regarded as a close approximation to the amount of rain falling annually on these catchment-basins, viz. 14,100 million cubic feet for the Vennachar catchment, and 14,700 million cubic feet for the Lubnaig catchment.

In the case of the Vennachar catchment a unique opportunity is presented for comparing the outflow with the rainfall, for a record has been taken twice a day of the depth of water flowing over a weir at the east end of Loch Vennachar since Loch Katrine has been made use of by the Glasgow Corporation as the source of the water-supply to that city. The readings of the depth of the outflowing water during the year 1869 have been calculated out, and the outflow for that year has been estimated at 9572 million cubic feet. The quantity of water supplied to Glasgow during the year 1869 is estimated at 1660 million cubic feet. There is thus an excess of rainfall, according to the mean of the three methods, over the overflow of 2860 million cubic feet. This difference must be accounted for by absorption, evaporation and loss of water by underground channels. The readings of the outflow for a series of twenty-five years or more would be a far more satisfactory basis for calculation than a single year's *readings (and the year 1869 was not an average, but a* very dry year), and it would be very interesting to have the average annual outflow calculated over the whole period during which the record has been kept, in the same way as the mean annual rainfall is calculated for a particular station. Records of the rainfall at high elevations in different parts of the catchment-basins would also be desirable in comparing the average annual rainfall with the average annual outflow.

Appended to the paper is an account of the geology of the district by Messrs. B. N. Peach, F.R.S., and J. Horne, F.R.S., based on materials collected during the Geological Survey of that region, and published by permission of Sir Archibald Geikie, the Director-General. A brief sketch is given of the geological structure of the area embracing the various lochs, which has an important bearing on the question of the evolution of the valley-system. It is shown that, along the Highland border, there is a great development of conglomerates, grits and greywackes, belonging partly to the crystalline schists and partly to the Old Red Sandstone. These strata, being vertical or nearly so, would be much less easily eroded than the gently inclined schistose rocks

lying to the north-west. Such an arrangement would naturally lead to the formation of narrow and comparatively flat-bottomed valleys behind rocky gorges, the latter being cut through the vertical beds of hard grit and conglomerate along the Highland border. Evidence is adduced to show how this remarkable structure likewise contributed to the erosion of rock basins during the glacial period. The glacial phenomena of the region are reviewed, which indicate at least two periods of glaciation ; one, when the ice-shed lay to the north of the area under consideration, when the ice-movement was independent of the existing valley-system, and when even the highest mountains were overridden by the ice. This great development was followed by a period of local glaciation, when the glaciers were confined mainly to the existing valleys. Lastly, the soundings of the various lochs are viewed in relation to the geological history of the area, and with reference to the question of the origin of the various lakes. It is shown that some of the lochs are typical examples of rock basins, that in some instances the deepest soundings occur in front of the rocky barriers at or near their outlets. Reference is made to all the important faults traversing the region, which have led to the more rapid disintegration of the materials, but though they have in certain cases produced modifications of the floors of the lakes, they cannot account for the excavation of the rock basins. The soundings of Loch Lubnaig reveal the striking fact that one of the deep basins in that lake lies on the upthrow side of the most powerful fault traversing the crystalline schists of that region. Messrs. Peach and Horne believe that the soundings of the various lakes in the basin of the Teith above Callander furnish strong evidence in support of Ramsay's theory of their excavation by ice-action.

The paper is illustrated by seven coloured maps, the first three showing on a small scale the orography and drainage areas, the surface geology and the rainfall of the district, the other four showing on a larger scale the bathymetry of the various lochs and the relief of the surrounding country. There are also numerous woodcuts, some of which are reproduced in this review.

IRON AND STEEL INSTITUTE.

THE annual meeting of the Iron and Steel Institute was held on Wednesday and Thursday, May 9 and 10, in the hall of the Institution of Civil Engineers, under the presidency of Sir William Roberts-Austen, K.C.B., F.R.S. The attendance of members was larger than at any previous gathering. The report of the council, which was read by the secretary, Mr. Bennett H. Brough, showed that the Institute is in a flourishing condition. The receipts last year were greater than in any previous year, 110 new members were added to the roll, the supply of original papers was well maintained, and a Royal Charter of Incorporation had been granted. After the usual formal business, the president presented the Bessemer gold medal for 1900 to Mr. Henri de Wendel, the eminent French metallurgist, in recognition of his great services to metallurgy in developing the iron-ore resources of French and German Lorraine. Mr. de Wendel having expressed his appreciation of the honour conferred upon him, Mr. Stead announced that he had decided to postpone the reading of his paper until the autumn meeting in Paris.

Mr. J. Riley then described the various attempts that have been made to use fluid metal in the open-hearth furnace. The results he obtained at Wishaw, in 1898, were encouraging, and experience over a considerable period show that great advantages are derived from the adoption of this method. The best future open-hearth practice, he considers, will include the use of fluid metal direct from the blast furnaces.

The next paper read was one of most conspicuous novelty, by Mr. B. Talbot, on the open-hearth continuous steel process. This process was introduced at the Pencoyd steelworks in Pennsylvania. The furnace used is a basic-lined tilting furnace of seventy-five tons capacity. Many thousands of tons of steel have been made by this method with very satisfactory results, all grades of steel having been produced. The cost and delay in charging cold material is avoided. There is a saving in fuel in charging molten pig iron. The demand for a large supply of good scrap is dispensed with. A regular supply of steel in any desired quantity and at frequent intervals is insured. There is an increased output, an increased yield, and a saving in repairs and in labour charges. At the same time it is possible to use very large furnaces, with consequent reduction in cost of production, without the necessity for very large cranes and ladles. A long discussion followed the reading of the paper, the opinion being general that the process is an important advance in open-hearth steel practice.

Mr. A. Greiner gave an account of the results obtained at the Cockerill works, Belgium, with the first blowing-engine worked by blast-furnace gas ever employed in any ironworks. This 600 horse-power engine has been running since November 20 last with unpurified gas taken from the Seraing blast-furnaces.

Baron H. von Jüptner submitted a further instalment of his researches on the theory of solution of iron and steel. He discussed the application of the laws of chemical mechanics in the case of iron carbon alloys, and showed what an important bearing thermo-chemistry possesses for a knowledge of the constitution of the alloys of iron and their alterations of state.

The meeting then adjourned until May 10, when Mr. C. Dellwik dealt with the manufacture and application of water-gas, describing the production of the gas by means of a simple apparatus with a degree of economy surpassing that of other less valuable gas. Whilst in the old processes the gas leaving the generator during the blow contains principally carbon monoxide and nitrogen, in the author's process it consists chiefly of carbon dioxide and nitrogen.

The subject of utilising blast-furnace slag is a fruitful source of inquiry, and a recent important development was dealt with by Mr. C. von Schwarz. This is a successful method of manufacturing cement from blast-furnace slag, recently employed in Germany and Belgium. The cement thus made obtains a higher price in the market than ordinary Portland cement.

Mr. L. F. Gjers and Mr. J. H. Harrison described an apparatus for equalising the varying temperatures of hot blast. Hitherto the hot blast has been allowed to enter the furnace as it left the stove, and in order to obviate the interference with the steady working of the furnace, the authors have devised an apparatus consisting practically of another small stove with a central division wall. It is filled with chequer work ; and the hot blast, entering at one side of varying temperature, is delivered out at the other side at an even mean temperature.

The form of ingot that would seem to be the most natural for the manufacture of a gun-tube or a propeller shaft is one with a circular section. Mr. F. J. R. Carulla, however, pointed out the drawbacks of this form, and showed that a polygonal ingot with concave sides answers the required conditions.

Mr. H. K. Scott contributed a paper on manganese ore deposits and mining in Brazil, giving a detailed account of the geological structure of the deposits, and of the economic development of the industry.

After the usual votes of thanks to the Institution of Civil Engineers, proposed by Sir John Alleyne, Bart., and to the president for his conduct in the chair, proposed by Mr. Carnegie, the proceedings terminated. Incidentally, Mr. Carnegie announced his intention of founding a scholarship in connection with the Iron and Steel Institute for the advancement of research in connection with iron and steel.

THE ROYAL SOCIETY CONVERSAZIONE.

THE general opinion of the scientific company at the Royal Society on Wednesday, May 9, on the occasion of the first of the two soirées held annually, was that novel and striking exhibits were not so numerous as in some exhibitions of previous years. The following were among the most noteworthy exhibits :—

Mr. Richard Kerr showed a clock controlled at a distance by wireless telegraphy of the Hertzian wave system. Mr. J. Wimshurst, F.R.S., exhibited an influence machine, constructed with twelve plates of vulcanite. Prof. Silvanus P. Thompson, F.R.S., showed some pretty electromagnetic experiments, one being the converse of De La Rive's experiment, using floating magnet instead of floating battery, and others showing new varieties of the De La Rive experiment (see p. 71). Prof. Minchin, F.R.S., showed that luminous flashes could be induced in a helium tube by Hertz waves.

An electric micrometer was shown by Mr. P. E. Shaw. The instrument was designed primarily to measure the small movements of a telephone diaphragm. A screw abuts on a system of three levers, set up on a strong wooden frame. By turning the